EOID System Model Validation, Metrics, and Synthetic Clutter Generation

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LONG-TERM GOALS

Our long-term goal is to accurately predict the capability of the current generation of laser-based underwater imaging sensors to perform Electro-Optic Identification (EOID) against relevant targets in a variety of realistic environmental conditions. The models will predict the impact of environmental variables (e.g. optical properties) as well as engineering variables (e.g. gains and aperture settings) on performance. The two most prominent technologies in this area are Laser Line Scan (LLS) and Streak Tube Imaging Lidar (STIL). Examples of systems using these technologies are the AN/AQS-14 (using LLS) and AN/AQS-20/X (using STIL) mine-hunting systems.

OBJECTIVES

Our objectives are to develop and validate EOID models and metrics for image synthesis and prediction of operator identification. When these models are developed, they will be incorporated into prototype tactical decision aids.

APPROACH

We have modified the Metron EODES software to represent LLS and STIL in terms of a set of parameters for each system. For either type of system, the choice of values for the parameters is based on those of existing systems. Sensor data collected during August 2001 field test from Areté, Raytheon and Northrop Grumman systems will serve to validate our models. Additional data from the September 2003 MIREM exercise will be used.

Statistical models of the ocean optical environment and system operating conditions were developed in order to represent the uncertainty in the model inputs for validation. This is needed in order to estimate the uncertainty associated with the validated model outputs.

The validation categories selected with these goals in mind is given in Table 1. The left column of the table describes the quantities that are compared between model and data, the right column describes the issue that the validation addresses.

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14. ABSTRACT
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Table 1. Categories for sensor-model validation.

Pure radiometry (mean signal levels)	Does the model predict mean laser-induced and solar-induced light levels correctly?
Stochastic noise processes	Does the model represent random receiver and environmental noise processes correctly?
Point Spread Function	Does the model represent the combined blurring effects of the system receiver and the ocean environment correctly?
Forward-scatter and back-scatter noise	Are volume backscatter processes correctly represented?
Range resolution and 3-D Edge response	Are range dependent blurring processes well-represented by the model?

WORK COMPLETED

The numerical methods for calculating the radiance were improved to improve the speed of the calculations. Several hardware-specific aspects of the Laser Line Scan system were added to the physics model to properly account for the impact of aperture alignment. The EODES imaging / image metric model was calibrated against the solar signals as measured by up- and downwelling sensors during the August 2001 test. The model point spread function was compared with separate calculations from an independent single scattering model, and a Monte Carlo scattering model, and agreement was found to be very good.

The model was successfully integrated into a system which allows for input of optical properties measured by the Battlespace Profiler, Slocum Gliders, and standard optical instruments. This system was then tested in a MIREM exercise in September 2003 with the AQS-24 Laser Line Scan and the Slocum Glider.

RESULTS

The EODES model uses the small angle scattering approximation for the ocean radiative transfer, as well as models of the components of the individual sensor systems. The AQS-24 Laser Line Scan gain and apertures are modeled explicitly to account for radiometry and for effects of aperture misalignment. Validation of the MTF of the ocean multiple scattering and attenuation effects were conducted initially using two independent model formulations: a Monte Carlo simulation and a single scattering approximation. For the scattering lengths typical of ocean waters and operational altitudes of the AQS-24, the beam spread function (or equivalently the point spread function) for the three models is shown in Figure 1.

The noise introduced by the sun can be significant for a Laser Line Scan system, and the model for upwelling solar radiance at the sensor due to water backscatter and bottom reflectance is shown against data from the August 2001 test. The increasing scatter at higher irradiance values is due to the increasing uncertainty in the optical properties as well as the path length as the sensor altitude above the bottom diminishes.

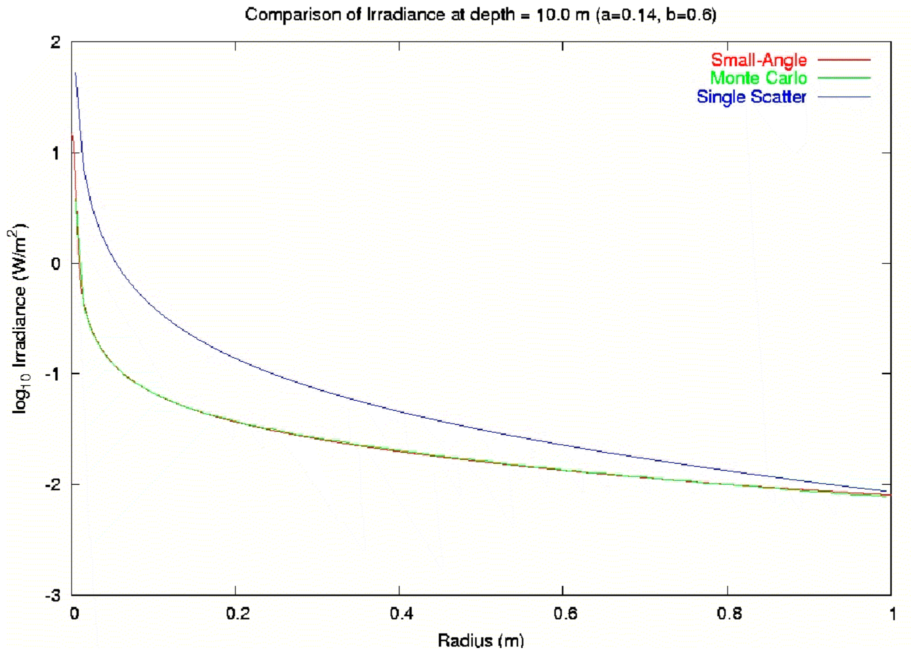

Figure 1. Comparison of Irradiance in Watts per square meter as a function of radius in meters for a monodirectional point source at altitude above bottom of ten meters. The attenuation coefficient is 0.14 per meter, and the scattering coefficient is 0.6 per meter. The figure shows good agreement between the EODES model and Monte Carlo model, and disagreement with the single scatter model.

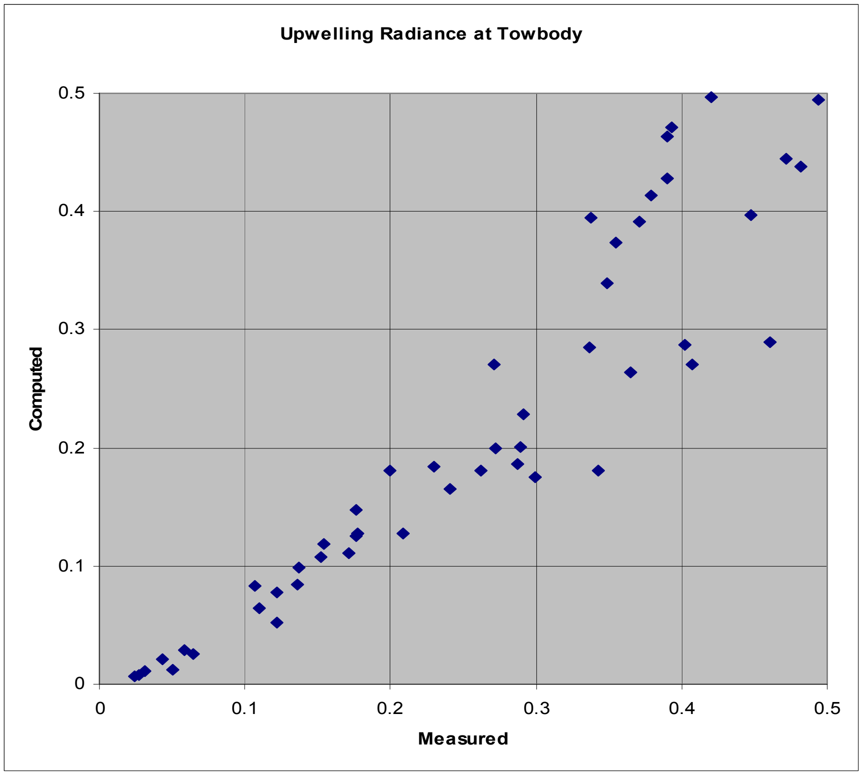

Figure 2. Comparison of solar backscatter model in EODES with data from August 2001 test showing computed upwelling radiance in watts per square meter per steradian versus measured radiance. The scatter lies slightly below the 45 degree line, and the scatter increases with increasing radiance.

IMPACT/APPLICATION

When completed, this work will support the completion of a validated Laser Line Scan and STIL EOID performance model for distribution and incorporation into Fleet Tactical Decision Aids.

TRANSITIONS

The models and metrics developed and validated by this work has been used to support a MIREM exercise by HM-14 in testing of the AQS-24 minehunting system.

RELATED PROJECTS

Airborne Laser Mine Detection System (ALMDS).
Rapid Airborne Mine Clearance System (RAMICS)

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